# CHAPTER 5

# CRACK AND JOINT MEASURING DEVICES

5-1. Purpose. In both new and existing structures the development of cracks and the movement of joints are indications of stresses on the structure that are sometimes above normal. In some cases these conditions can be anticipated beforehand while in others the situation arises spontaneously. Measurement of these areas of distress is provided through crack and joint displacement indicators that can either be installed in predetermined locations to monitor expected cracks or observe joint behavior, or placed at the site of a known crack or joint as the need arises for its monitoring.

5-2. Description of the Instruments. These instruments are either manual in operation or utilize one of the electrical principles adaptable to displacement measurement. The monolith joint displacement indicator, relative movement indicator, ball-n-box gages, multiposition strain gage, dial gage, "L" shaped gage, and scratch gage are all manual gages requiring periodic reading to determine the displacements. The Carlson joint meter and the multiple position borehole extensometer are electrical instruments utilizing the change in resistance of a stretching wire as a measure of strain.

5-3. Instrument Details and Characteristics.

a. Relative Displacement Instruments. There are three types of gages in this category, the monolith joint displacement indicator, the relative movement indicator, and the ball-n-box gage. All three instruments use the same procedures to monitor monolith movement in three dimensions. They function by measuring the relative displacement between two surfaces of the instrument attached to opposite sides of a crack or joint. As the crack or joint moves, the two halves of the gage move relative to each other. The monolith joint displacement indicator consists of two cold finished, SAE 1018 steel bars as shown in Figure 5-1 and Plate 5-1. These bars are 1-1/2- by 1-1/2-in. in cross section with 1-1/2- by 3-in. measurement surfaces faced with at least 1/8-in. hard brass, machine-ground to a smooth surface. The pairs of opposing finished surfaces, C-C', D-D', and E-E', shown in Plate 5-1, must be parallel to each other.

Figure 5-1. Monolith Joint Displacement Indicator. (Photo by WES)

b. The Relative Movement Indicator. This gage consists of two steel angles that bolt to either side of the crack or joint to be measured. The gage is shown in Plate 5-2. The indicator arm bolts to the flange of one of the angles and consists of a 5/8-in. diameter threaded stainless steel shank with a l-in. diameter stainless steel ball soldered to the end of the shank with silver solder. The ball sits in a 1- by 1-1/2-in. cutout in the flange of the remaining angle. Accessories necessary to measure movement with this gage include a setting and checking gage, shown in Plate 5-2, and a conventional 24-leaf automotive thickness gage (.0015- through 0.32-in.). This gage is also described in ETL 1110-2-118.

c. Ball-n-box Gage. This third type of relative displacement indicator, shown in Figure 5-2 and Plate 5-3, will measure relative movement in three orthogonal directions across a crack or joint. The gage consists of a chrome-plated steel or brass rod with a steel ball silver soldered to the tip of the rod attached to the structure on one side of the crack or joint and a hollow, box-type aluminum frame bolted to the structure on the opposite side of the crack or joint. The three reference faces of the box have been machined orthogonal to each other.

(1) Measurement is made by the use of a dial gage mounted on a base plate. The foot of the dial gage is placed on the steel ball and moved until the minimum reading on the dial gage is achieved. This point will be the highest point on the steel ball with respect to the face of the hollow box from which the measurement is being made. This minimum dial gage reading is recorded and compared to the previous reading for that face of the cube to determine the relative movement of the two sides of the joint or crack.

(2) The accuracy of measurement has been recorded down to 0.001 in. and good consistency of measurement has been achieved even with multiple instrument readers. More detailed information about this instrument can be obtained from the Omaha District Corps of Engineers.

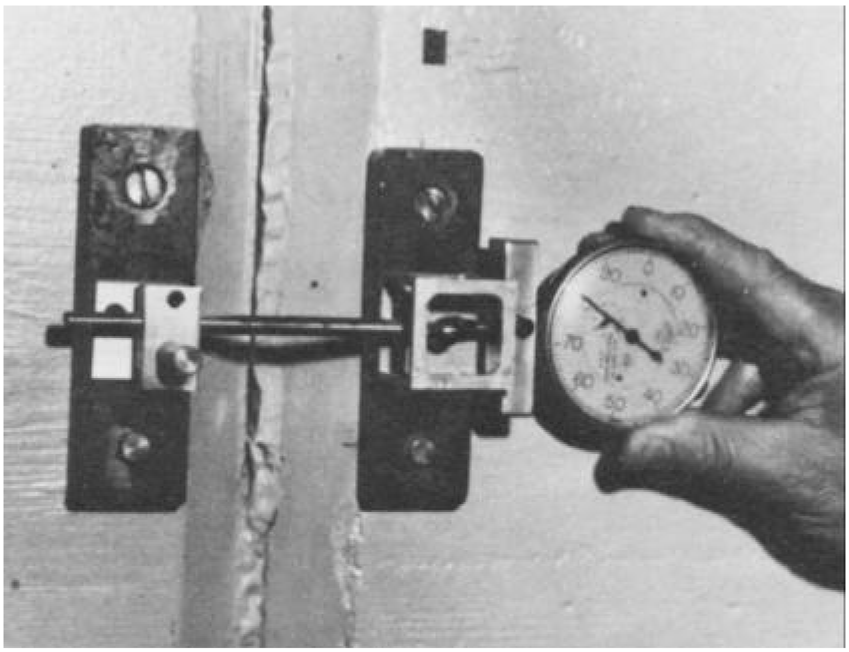
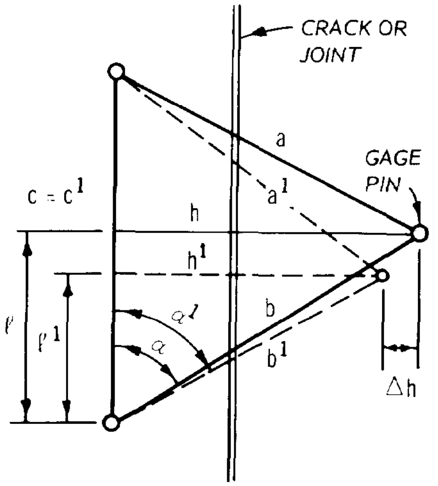


Figure 5-2, Ball-N-Box Gage. (Photo by WES)

d. Multiposition Strain Gage. This measurement technique utilizes the Whittemore strain gage described in paragraph 2-28b, and three brass inserts that are placed in the concrete on either side of the crack or joint to be measured. It measures movement in two dimension in the plane of the surface on which the crack appears by measuring the distance between the three inserts and by using triangulation principles to determine the horizontal and vertical components of the movement. Figure 5-3 shows the gage setup and gives the equations necessary for calculation. Two insert pins, one placed on each side of the crack or joint, can also be used; however, this setup will only measure the component of crack movement parallel to the line of the gage points.




$$\cos\alpha = \frac{b^2 + c^2 - a^2}{2bc}$$

$$\ell = b\cos\alpha = \frac{b^2 + c^2 - a^2}{2c}$$

$$h = \sqrt{b^2 - \ell^2}$$

$$\Delta\ell = \ell - \ell^1 \qquad \Delta h = h - h^1$$

TO OBTAIN $\cos\alpha^1$, $h^1$ AND $\ell^1$ SUBSTITUTE PRIMED VALUES OF a, b, AND c ABOVE.

Figure 5-3. Multiposition Strain Gage. (Prepared by WES)

e. "L" Shaped Gage. The gage shown in Figure 5-4 is another variation of the two dimension measurement gages. It consists of two "L" shaped plates fastened to the concrete on opposite sides of the crack, as shown in the figure. Measurement is made with calipers at the openings between the two gages. This gage will measure movement in the two component directions in the plane of the crack. In addition to translation, this gage will also measure rotation of one side of the crack with respect to the other side. By measuring the gage openings on both sides of the gage, the angle of rotation since the last measurement had been made can be calculated.

f. Dial Gage. The dial gage, shown in Figure 5-5, is intended to measure only expansion and contraction of the crack or joint. The instrument consists of two bars attached to the concrete on opposite sides of the joint with one bar having a mount to accept a dial gage and the other a foot on which the plunger of the dial gage rests. The whole instrument is housed in a metal box with a plexiglass viewing cover, and is attached to the face of the monolith to one side of the crack. Its accuracy is dependent upon the accuracy of the dial gage used.

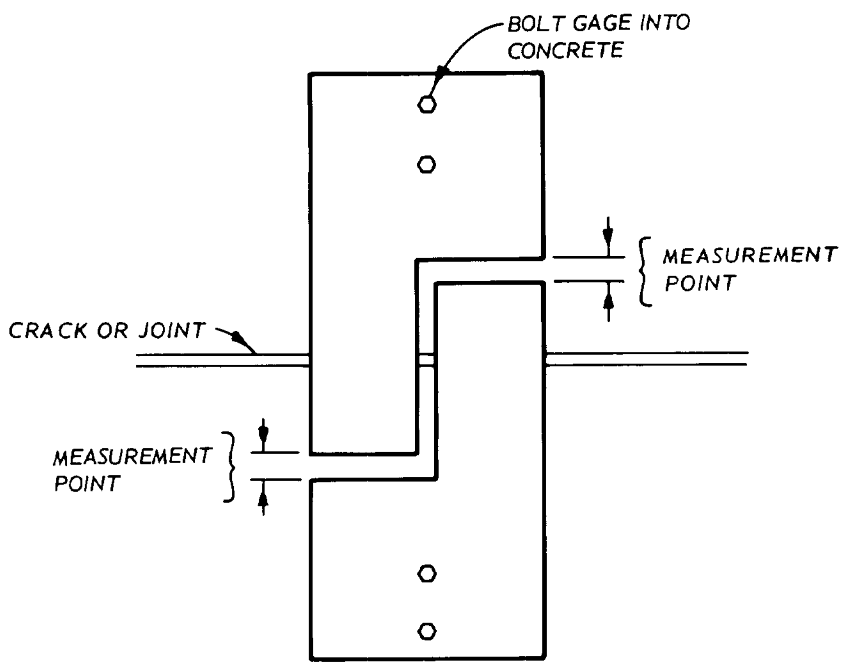



Figure 5-4. "L" Shaped Gage. (Prepared by WES)

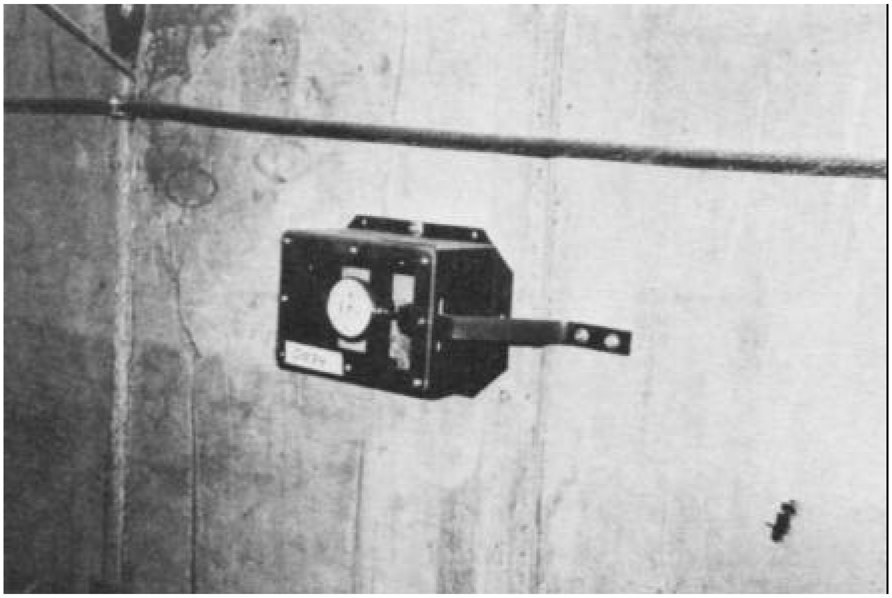


Figure 5.5. One Dimensional Dial Gage. (photo by WES)

g. Scratch Gage. The scratch gage is a mechanical instrument that provides a continuous history of movements, by scribing the movement of one surface with respect to another, on a metal plate. It is described in detail in paragraph 2-28c as a strain measuring instrument, but it also can be used to measure crack movement. The scribings on the ring will represent both tension and compression movements of the crack up to approximately 0.20 in. Since the gage is restricted to movement coincident with its longitudinal axis, the gage must be-oriented with its longitudinal axis aligned with the direction of crack movement.

h. Joint Meter. The Carlson joint meter is an electrical movement gage that measures movement as a function of the change in resistivity of a stretching wire. It is intended to be used as an embedment gage, as described in paragraph 2-4 in the strain instrument portion of this manual; however, when mounted as shown in Figure 5-6, it can be used to monitor crack or joint movement at the surface of a structure. Each end of the joint meter must be securely attached to the monolith and span the crack or joint to be monitored.

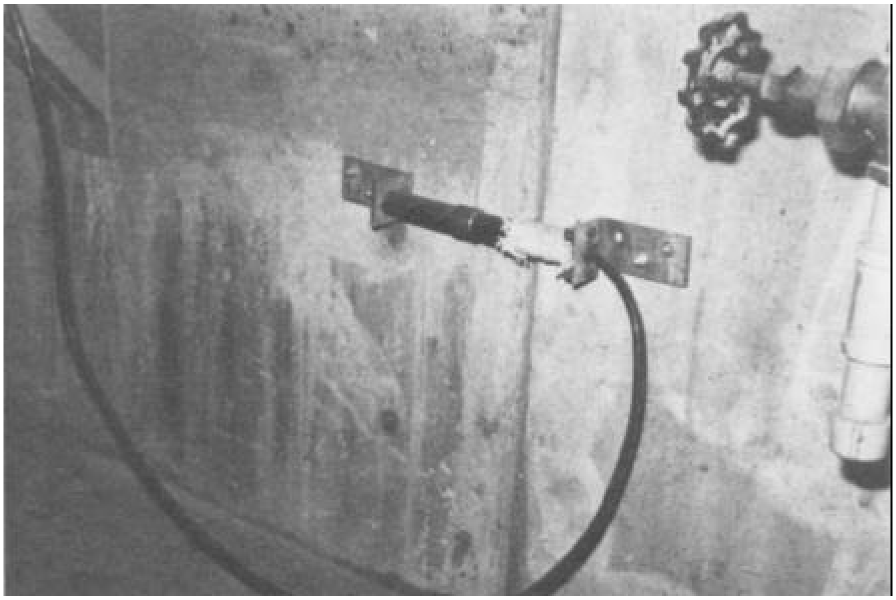


Figure 5-6. Carlson Joint Meter. (Photo by WES)

i. Multiple Position Borehole Extensometer (MPBX). This instrument is well suited to measuring movement of cracks that are not surface accessible. The instrument, as shown in Figure 5-7, is fitted into a borehole and anchored at eight locations. These locations can be between cracks in the interior of a structure to monitor how the concrete is moving. The MPBX measures the relative displacement of the borehole anchors which are mechanically fixed to the wall of the borehole. Each anchor is connected to a tensioning wire which is attached to the sensing head. As the anchors move, they in turn move a cantilever in the sensing head which is connected to an electrical transducer that records the movement of the cantilever.

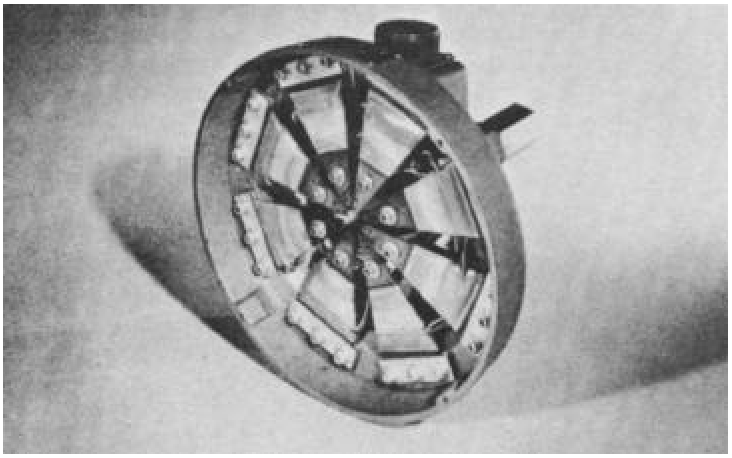


Figure 5-7. Multiple Position Borehole Extensometer (Courtesy of Terrametrics, Inc.).

j. Portable Crack Measuring Microscope. For purposes of measuring cracks conveniently, without installation of a gage, Du Maurier Company, Elmira, NY, manufactures a shirt pocket inspection and measuring microscope of high quality. It is a four lense, prefocused optical system of about the same size and shape as a fat ink pen. It comes in 10X, 20X, 40X, and 50X powers with field of view range of .265-, .190-, .082-, and .065-in. Reading is accomplished by holding the tip of the microscope over the crack, sighting through the eyepiece, and tilting it until the crack comes into focus. At that point the crack width is read directly from the scale superimposed on the field of view. All scales are direct-reading and accurate to within 1 percent.

5-4. Instrument Installation.

a. Personnel. The joint and crack measuring instruments covered in this section are primarily intended to be installed after the completion of the construction either at joints that become suspect of excessive movement or at cracks that develop in the structure. The installation of most of these gages requires secure attachment of two halves of the gages to opposite sides of the crack or joint. This can generally be accomplished by one engineer and the necessary crew of workers to install the instruments. In most cases it will be necessary to drill holes in sound concrete on either side of the discontinuity and install either the gage or an anchor. A grouting crew will be necessary to grout around instruments such as the monolith joint displacement indicator installed in drilled holes.

b. Monolith Joint Displacement Indicator.

(1) This measurement indicator is directly embedded into the structure to be monitored. Two drill holes 3-in. in diameter and at least S-in. deep should be drilled perpendicular to the plane of the surface to be monitored approximately 13 in. on either side of the crack or joint to be measured. The drill holes should be oriented on a line parallel to the direction of major crack movement; for example, if a crack is oriented at 45° to the vertical and it is determined that the major direction of movement of the two cracked faces will be horizontal, then the drill holes should be placed on a horizontal line on either side of the crack.

(2) The gage is installed by filling the 3-in. diameter holes with quick-setting grout that is of a non-shrink nature, and inserting the anchor ends of the gage into the fresh grout. Special care must be taken to assure that the two halves of the gage are installed such that their machined reading faces remain parallel. This can be accomplished by making a template on which to fasten both halves of the gage in their parallel working orientation in order to hold them in place until the grout hardens. This template is shown in Figure 5-8. Once the grout has hardened, the template can be removed.

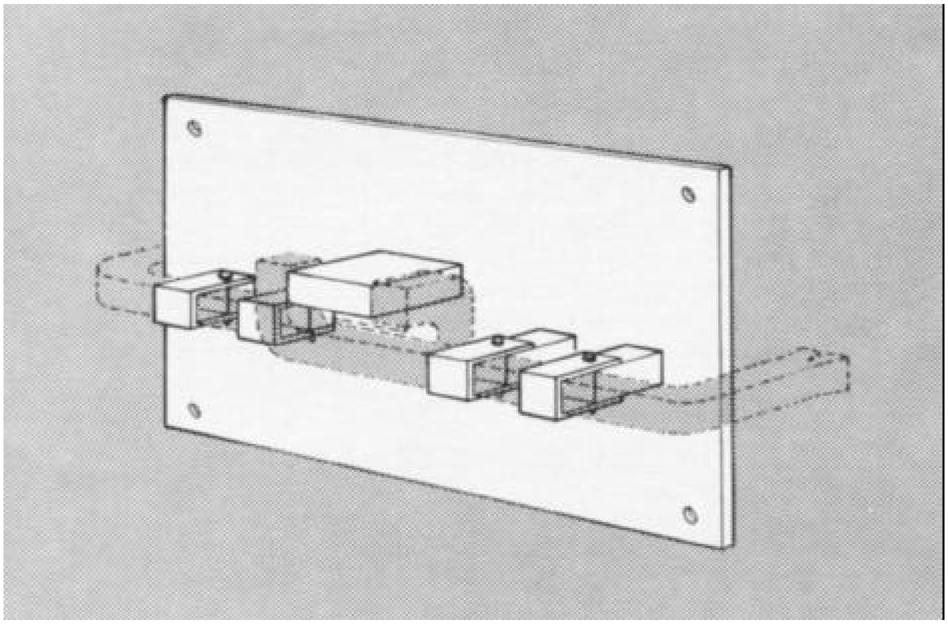


Figure 5-8. Mounting Template for Monolith Joint Displacement Indicator. (Prepared by WES)

c. Relative Movement Indicator. The gage is installed with one angle on each side of the crack or joint to be monitored. As mentioned in paragraph b above, the major direction of the movement for this gage should also be determined and the gage installed such that the longitudinal axis of the indicator arm is parallel to the major direction of movement. The installation consists of de-burring the concrete in the area of installation and drilling four 11/16-in. diameter-holes in the wall utilizing the "Wall Drilling Template" shown in Plate 5-2. Concrete anchors designed to fit these holes should then be installed. JETLOCK concrete anchors, manufactured by LOCTITE Corporation, Newington, CT, have been used to anchor the bolts into the concrete. Coat the threads of all bolts with an appropriate sealant. The assembly is installed and adjusted to the dimensions shown in Plate 5-2 by the party chief using the setting and checking gage shown on the drawing. The 0.250-in. dimensions are the dimensions that will be logged and these shall be within 0.005 in. of the 0.250 after installation and adjustment. After a 24-hr setup period for the sealant, the dimensions shall be checked and logged and these will be used as the gage initial reading.

d. Multiposition Strain Gage.

(1) Installation of this gage consists of installation of the reference points in which to insert the Whittemore type mechanical strain gage. The brass or stainless steel reference points are installed in sound concrete on either side of the joint or crack to be measured. Either two or three points may be installed depending whether movement in one or two directions is to be monitored. If it is desired to monitor movement in two directions, three points should be installed. They should be arranged in the shape of an equilateral triangle with the distance between each reference point approximately equal to the gage length of the reading device. If a Whittemore gage is used, the gage length can be adjusted to 2-, 4-, 6-, 8-, or 10-in. intervals. For purposes of measuring crack width, it is recommended that at least an S-in. gage length be used to insure that the reference points are embedded in sound concrete. On one side of the crack or joint two pins should be installed on a line perpendicular to the major direction of movement of the crack and the remaining reference point should be installed on the other side of the joint a distance equal to the gage length from both reference points on the first side of the crack.

(2) The gages should be set flush with the concrete surface and just prior to the first reading should be center punched to accept the cone-shaped point of the Whittemore gage. If only vernier calipers are available to read the distance between reference points, the pins must be set to protrude above the concrete surface enough to allow the calipers to be used. With this setup there is the danger that the points will be accidentally damaged or bent. This method should only be used when a Whitemore type strain gage is not available and if it is used the points should be protected against accidental damage.

(3) A two-pin system consisting of one pin on each side of the crack or joint, oriented parallel to the major direction of crack movement, may be suitable in some cases. Measurements will indicate opening and closing of the crack but no other movement can be detected.

e. Dial Gage. The dial gage is mounted on a bar assembly attached to one side of the crack and the dial gage oriented such that the longitudinal axis of the plunger is parallel to the major direction of crack movement and seated against a foot attached to the concrete on the other side of the crack. The entire assembly is then housed in a protective case that is attached to the concrete on the same side of the crack as the dial gage. Care should be taken to insure that the plunger of the dial gage is seated in the center of the foot so that minor movement will not cause the dial gage plunger to slip off the reference foot.

f. Scratch Strain Gage. The scratch strain gage is installed with the recording or scratching arm on one side of the joint and the target or scratched plate on the other. Special precautions should be taken when installing the scratch strain gage to insure that the longitudinal axis of the gage is oriented parallel to the direction of crack movement. In the case of strain measurements the length between points of attachment of the gage to the concrete must be accurately known to determine the strain. In the case of crack measurement this is not necessary because all the expansion or contraction will take place at the crack. If mechanical fasteners are used, the distance over which the strain is being measured is the distance between the fasteners; however, if the gage is attached by use of an adhesive, the adhesive should be confined to a limited area of the gage such that accurate measurements of the distance between adhesive areas can be made.

g. Joint Meter. The joint meter measures movement parallel to its longitudinal axis. For this reason the gage must be installed with the longitudinal axis of the gage parallel to the major direction of crack or joint movement. If there is movement in two directions, the joint meter will indicate the distance between points of fastening of the meter, but will not differentiate between horizontal or vertical movement. The cable from the meter should be secured to the floor or wall of the gallery so that it will not be pulled loose or damaged by accident.

h. Multiple Position Borehole Extensometer.

(1) Anchor Installation. In order for this instrument to function properly, care must be exercised in its installation. The anchors must be pushed down the borehole with a special installation tool. This tool is designed to allow the anchor to move freely when being pushed into the hole, but when it is in place and the setting tool is retracted, its design is intended to set the anchor against the sides of the borehole. The anchors must be placed carefully such that the measuring wire which is attached to the anchor before it is placed in the hole will not get tangled or wrapped around the other wires in the hole.

(2) Head Installation. The borehole extensometer head contains the transducers that monitor the motion of the concrete in contact with the extensometer's anchors. The head should be recessed in the concrete such that it will be protected when the installation is complete. A cover should be placed over the recess to add extra protection to the electrical mechanisms in the head.

5-5. Collection of Data.

a. The data sheets for recording the readings of the various instruments mentioned in this chapter should be devised to suit the type of movement indicator that is being monitored. Plates 5-4 through 5-8 are suggested field data sheets for the various gages reported here. They may be used in their entirety or tailored to the user's needs.

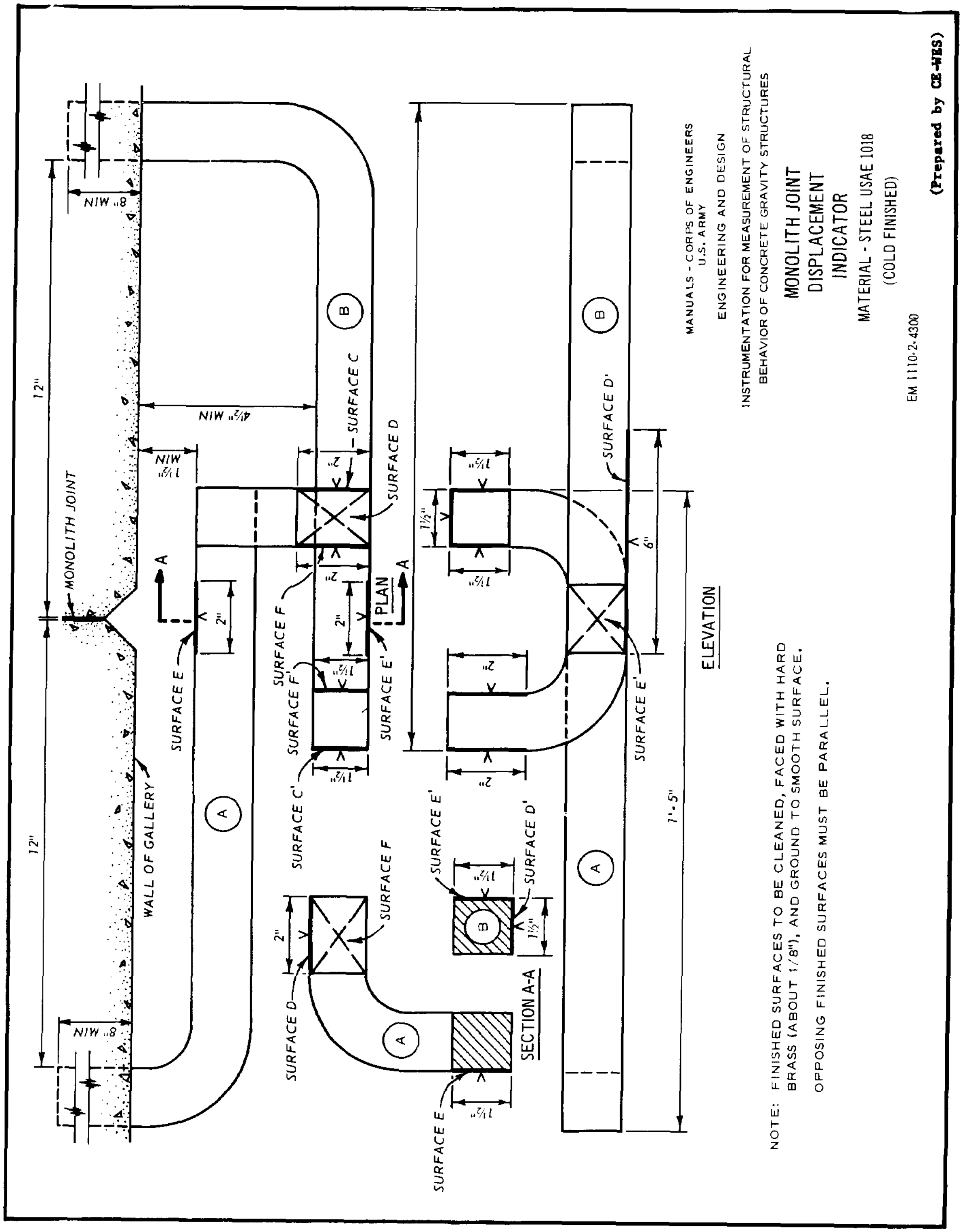
b. The peripheral information collected when each gage is read should include at least all of the following: the name of the structure at which the gage is located, the date upon which the readings are taken, the time the readings are taken, the temperature at the gage location, and the ambient temperature at the site of the structure, and pertinent pool elevations, The time of day and temperatures should be recorded to adjust the gage for temperature expansion or contraction. They also help identify the cause of the structure movement. The pertinent pool elevations are necessary such that it can be known what loading conditions the structure is subjected to. Additional information that is deemed pertient by the reading party chief should also be included.

c. All the gages in this chapter have relatively direct field reading values that can be recorded directly from the instrument or readout device onto the data sheet. However, the scratch strain gage must be read under a microscope with calibrated eyepiece. This should be done either in a laboratory or field office where the movements can be accurately read and recorded. A special microscope for reading the scratch strain gage (Figure 5-9) is available from Prewitt Associates, Lexington, KY. It is a small microscope with calibrated eyepiece, attached lighting source, and a rotating device to change the position of the target while it is under the microscope.

d. The data sheets are set up to read a number of different gages at various locations all within the same reading period. This is done to have a record of all movements on a certain date on one sheet and that comparisons with data taken on other dates will only require two data sheets. Protection of accumulated data should be accomplished in the same manner as that described in paragraph 2-24b of Chapter 2.

Figure 5-9. Scratch Strain Gage and Reading Microscope (Courtesy of Prewitt Associates).

5-6. Reading Schedules. The frequency of readings should be governed by the location and type of crack or joint being studied. In situations where a new crack has formed it is advisable to read the gages at least weekly until the movement of the crack is better understood. Also in the case of a lock wall reading with the lock empty and then lock full may be appropriate. Readings every month may be suitable on some portions of a dam. After the rate, amount, and direction of movement have been determined, the frequency of readings should be adjusted as required by the behavior of the crack or joint.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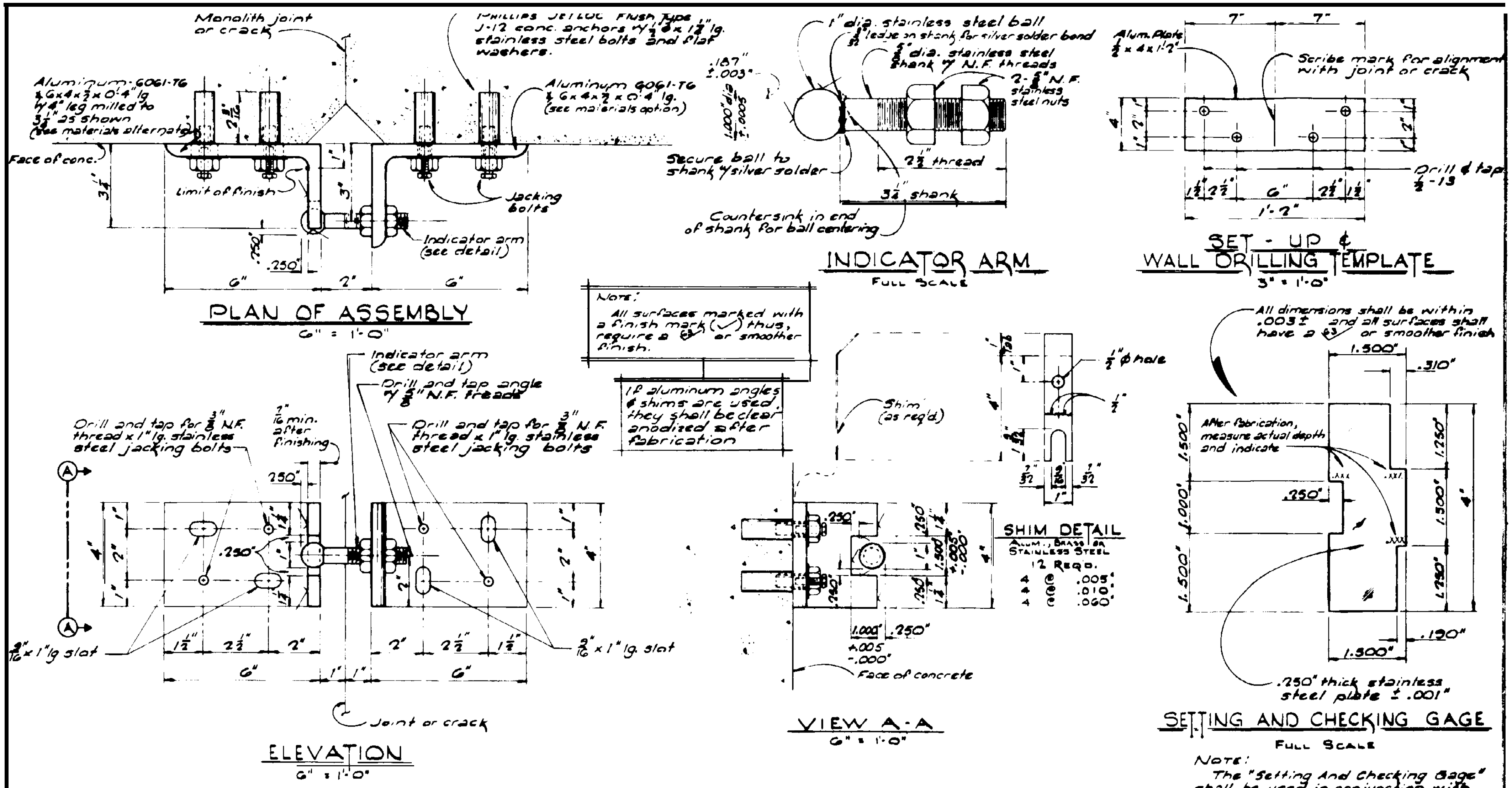
INSTRUMENTATION FOR MEASUREMENT OF STRUCTURAL
BEHAVIOR OF CONCRETE GRAVITY STRUCTURES
MONOLITH JOINT
DISPLACEMENT
INDICATOR
MATERIAL - STEEL USAE 1018
(COLD FINISHED)
EM 1110-2-4300
(Prepared by CE-WES)
NOTE: FINISHED SURFACES TO BE CLEANED, FACED WITH HARD
BRASS (ABOUT 1/8"), AND GROUND TO SMOOTH SURFACE.
OPPOSING FINISHED SURFACES MUST BE PARALLEL.
PLAN
ELEVATION
SECTION A-A
MONOLITH JOINT
WALL OF GALLERY
8" MIN
4½" MIN
1½" MIN
12"
12"
2"
1½"
6"
1'-5"
SURFACE C
SURFACE C'
SURFACE D
SURFACE D'
SURFACE E
SURFACE E'
SURFACE F
SURFACE F'
A
B




*Note:* The "Setting And Checking Gage" shall be used in conjunction with a 24 leaf automotive thickness gage (.0015" thru .032") for subsequent periodic readings.

*Materials Alternate*

The 6 x 4 x 1/2 angles may be stainless steel or heavy chrome plated mild steel.

If the chrome plated steel option is selected the threads for the jacking bolts and indicator arm shall be protected during the chrome plating process to assure proper thread fit.

*Installation Procedure*

De-burr concrete in the installation area. Drill 4-11/16" Ø holes in wall utilizing "Wall Drilling Template" and install "JETLOC" concrete anchors.

Treat threads of and for 1/2" Ø and 3/8" Ø bolts with "LOCQUIC CLEANER" and "LOCTITE SEALANT", Grade "A" (Loctite Corporation, Newington Conn.)

Install and adjust assembly to dimensions shown on the drawing using "Setting And Checking Gage", slotted holes, shims and jacking bolts as required. The .250" dimensions are the dimensions which will be logged and these shall be within .005" of the .250" after installation and adjustment.

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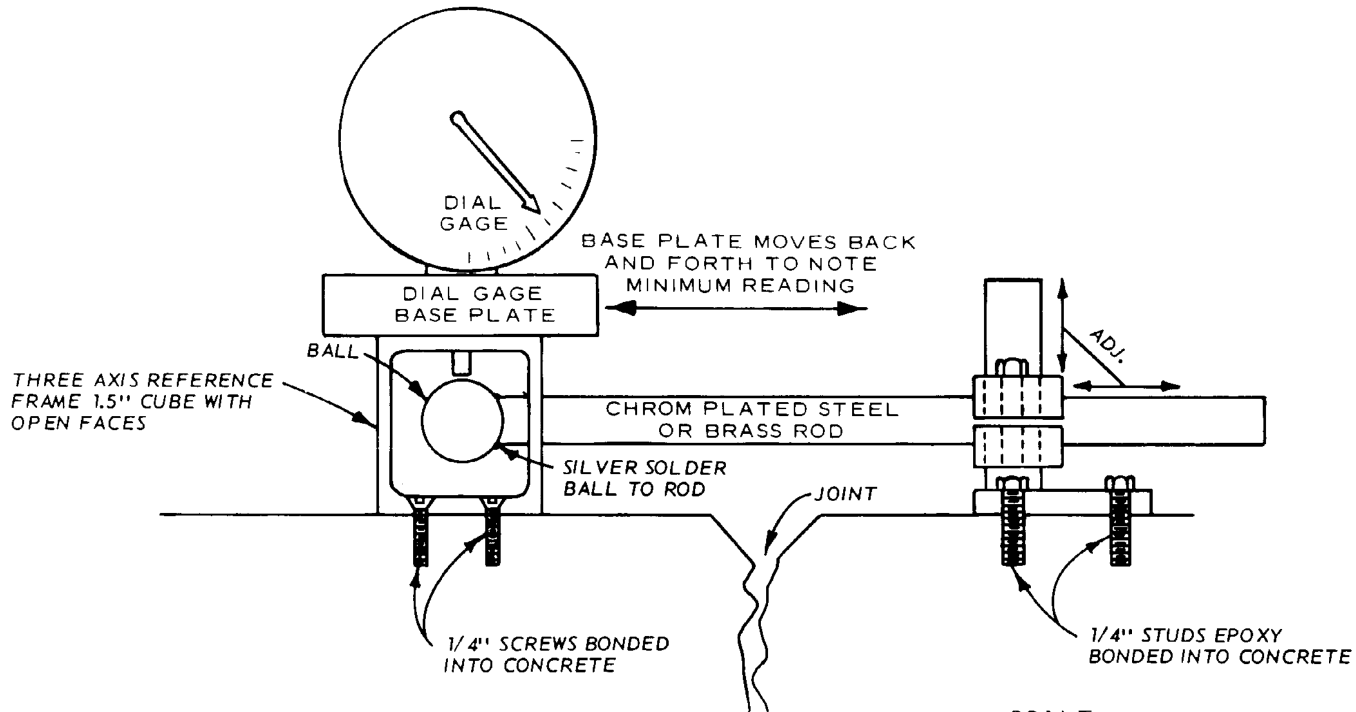
INSTRUMENTATION FOR MEASUREMENT OF STRUCTURAL BEHAVIOR OF CONCRETE GRAVITY STRUCTURES
RELATIVE MOVEMENT INDICATOR

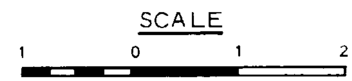
EM 1110-2-4300

(Prepared by CE-WES)

PLATE 5-2




NOTE: THIS UNIT IS BEING USED WITH GOOD RESULTS TO MEASURE MOVEMENT ACROSS JOINTS IN CONCRETE STRUCTURES. THE REFERENCE FRAME HAS PRECISELY MACHINED FACE SO THAT THE DIAL GAGE BASE PLATE CAN BE MOVED TO THREE ORTHAGONAL FACES. SKETCH SHOWS DIAL GAGE POSITION FOR MAKING VERTICAL MOTION MEASUREMENT.

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ENGINEERING AND DESIGN

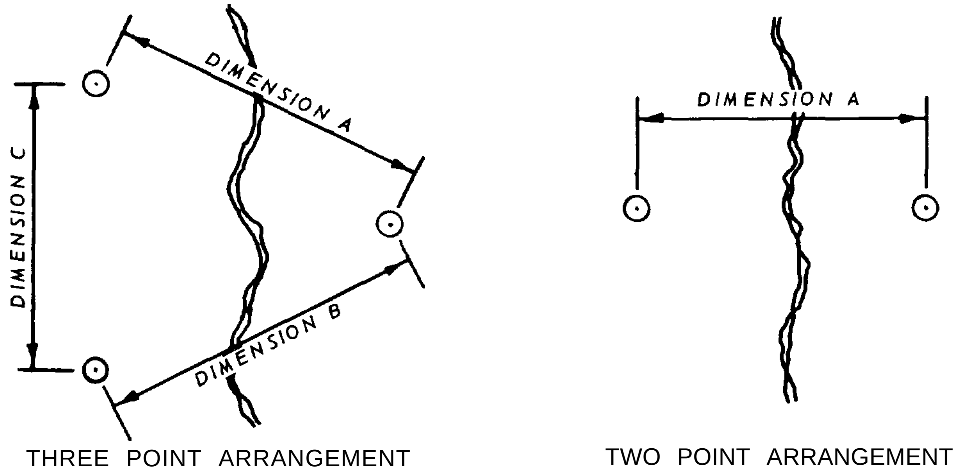
INSTRUMENTATION FOR MEASUREMENT OF STRUCTURAL BEHAVIOR OF CONCRETE GRAVITY STRUCTURES

BALL-N-BOX INSTRUMENT
FOR MEASURING MOVEMENT ACROSS JOINTS IN CONCRETE STRUCTURES

EM 1110-2-4300

(Prepared by CE-WES)

MULTI POSITION STRAIN GAGE FIELD DATA SHEET




PROJECT: ____________________

DATE: ____________________ TIME: ____________________

TEMPERATURE: ____________________

PERTINENT POOL ELEVATIONS:

UPSTREAM: ____________________ DOWNSTREAM: ____________________

LOCK FULL: • LOCK EMPTY: •

FOR INITIAL READING SEE SHEET DATED: ____________________

| GAGE LOCATION | DIMENSION A | DIMENSION B | DIMENSION C |
|---|---|---|---|
| | | | |
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COMMENTS:

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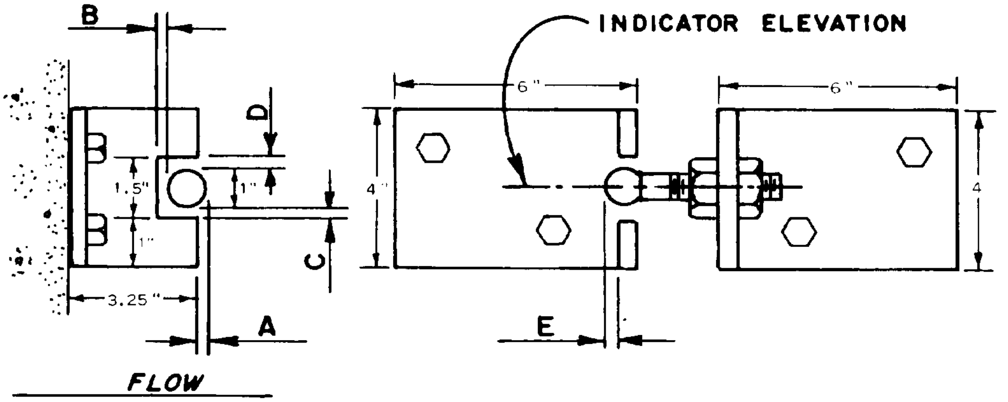
(Prepared by WES)




MOVEMENT INDICATOR

| PROJECT: | | DATE: | TIME: | POOL ELEV.<br>U. S.<br>D.S. | | OUTSIDE AIR TEMP. |
|---|---|---|---|---|---|---|
| LOCATION OF MEASUREMENT | DIMENSIONS (IN INCHES) | | | | | |
| JOINT OR CRACK | A | B | C | D | E | INDICATOR ELEVATION |
| | | | | | | |
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(Prepared by WES)

Plate 5-5

DIAL GAGE CRACK WIDTH INDICATOR
FIELD DATA SHEET

PROJECT: ____________________

DATE: ____________________ TIME: ____________________

TEMPERATURE: ____________________

PERTINENT POOL ELEVATIONS:

UPSTREAM: ____________________ DOWNSTREAM: ____________________

LOCK FULL: ☐ LOCK EMPTY: ☐

FOR INITIAL READING SEE SHEET DATED: ____________________

| GAGE LOCATION OR IDENTIFICATION | INITIAL READING | PRESENT READING | CRACK WIDTH |
|---|---|---|---|
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COMMENTS:

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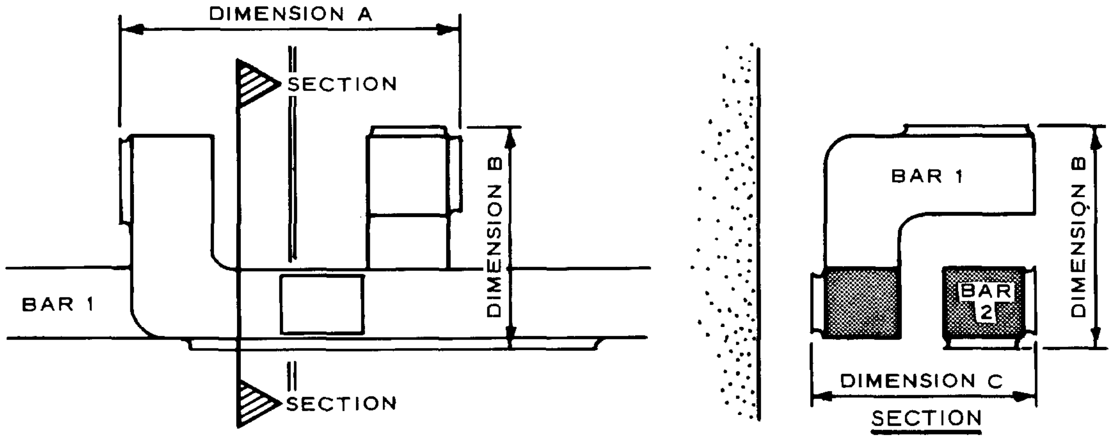
(prepared by WES)




PROJECT: ____________________

DATE: ____________________ TIME: ____________________

TEMPERATURE: ____________________

PERTINENT POOL ELEVATIONS:

UPSTREAM: ____________________ DOWNSTREAM: ____________________

LOCK FULL: ☐ LOCK EMPTY: ☐

FOR INITIAL READING SEE SHEET DATED:

| GAGE LOCATION | DIMENSION A | | | DIMENSION B | | | DIMENSION C | | |
|---|---|---|---|---|---|---|---|---|---|
| | READING | | DIFF. | READING | | DIFF. | READING | | DIFF. |
| | INITIAL | PRESENT | | INITIAL | PRESENT | | INITIAL | PRESENT | |
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COMMENTS:

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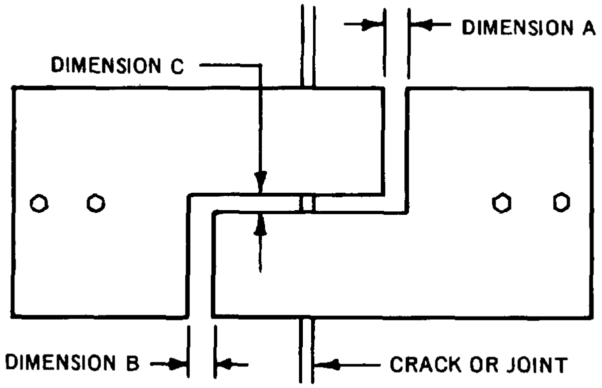
(Prepared by WES)



Plate 5-7

## RELATIVE MOVEMENT INDICATOR FIELD DATA SHEET




PROJECT: ____________________

DATE: ____________________ TIME: ____________________

TEMPERATURE: ____________________

PERTINENT POOL ELEVATIONS:

UPSTREAM: ____________________ DOWNSTREAM: ____________________

LOCK FULL: ☐ LOCK EMPTY: ☐

FOR INITIAL READING SEE SHEET DATED: ____________________

| GAGE LOCATION | DIMENSION A | | | DIMENSION B | | | DIMENSION C | | |
|---|---|---|---|---|---|---|---|---|---|
| | READING | | DIFF. | READING | | DIFF. | READING | | DIFF. |
| | INITIAL | PRESENT | | INITIAL | PRESENT | | INITIAL | PRESENT | |
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COMMENTS:

SHEET OF

(Prepared by WES)



Plate 5-8